System for Route Optimization in Dynamic Transport Environment

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Smart Freight Delivery in Medium City Based on GPS Big Data

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Workshop on Smart Urban Mobility
Edinburgh Napier University, 26-27 November 2015

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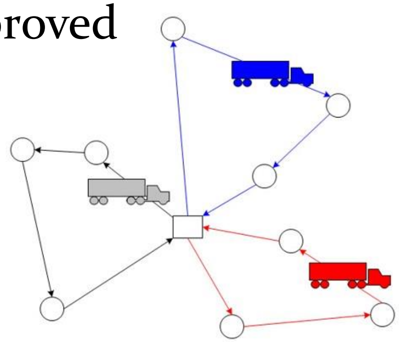
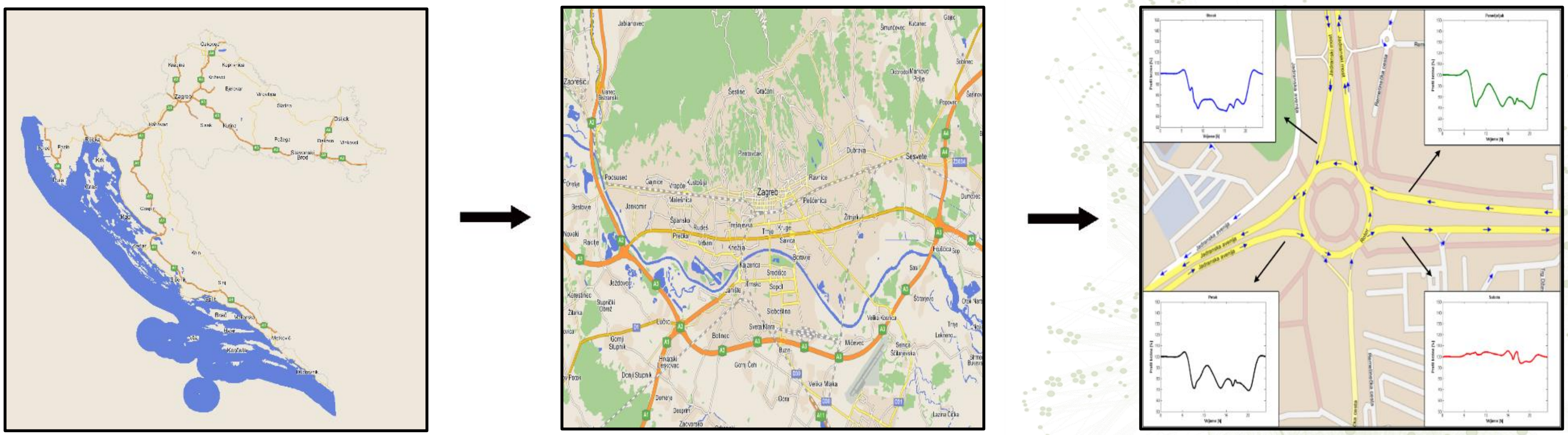
Smart Freight Delivery

- **Solutions for urban freight delivery** - finding optimal routes to serve customers by a fleet of vehicles
- **Most current solutions** – are based on static graphs where constant edges are represented by expected constant speed
- Recent approaches take into account that times of delivery depend on **departure times** from customers
- Using **time dependent shortest path software components** which use **speed profiles**, solutions for freight delivery can be improved



What are speed profiles?

- Speed profiles are representations of speed change for specific roads (link) during the day
- Speed profiles are derived by aggregating and processing recorded GPS data



GPS data set and big data

- The GPS data (~6.5 billion records) were recorded during a five year period between August 2009 and October 2014 by ~4200 tracked vehicles

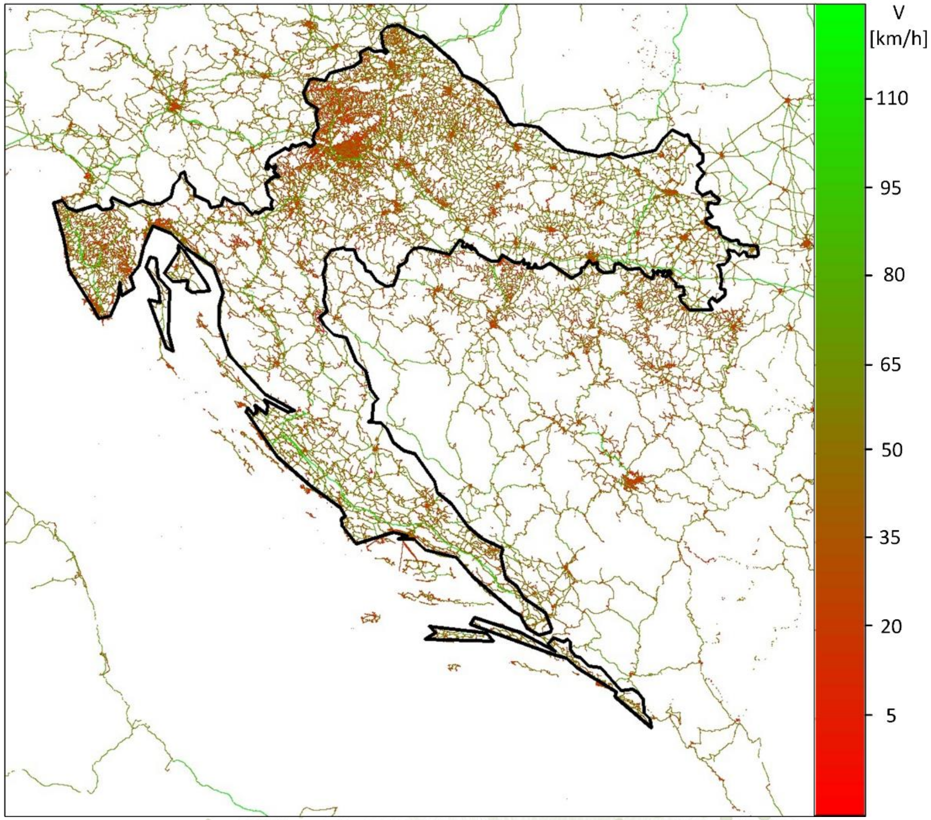
- If the tracked vehicle was in driving mode the GPS signal was recorded approx. every 100 m, otherwise the GPS signal was recorded every 5 minutes

- When the GPS signal occurs, vehicle speed is calculated as covered distance from last recorded GPS signal per elapsed time:

$$v_{veh} = \frac{s}{t_i - t_{i-1}}$$

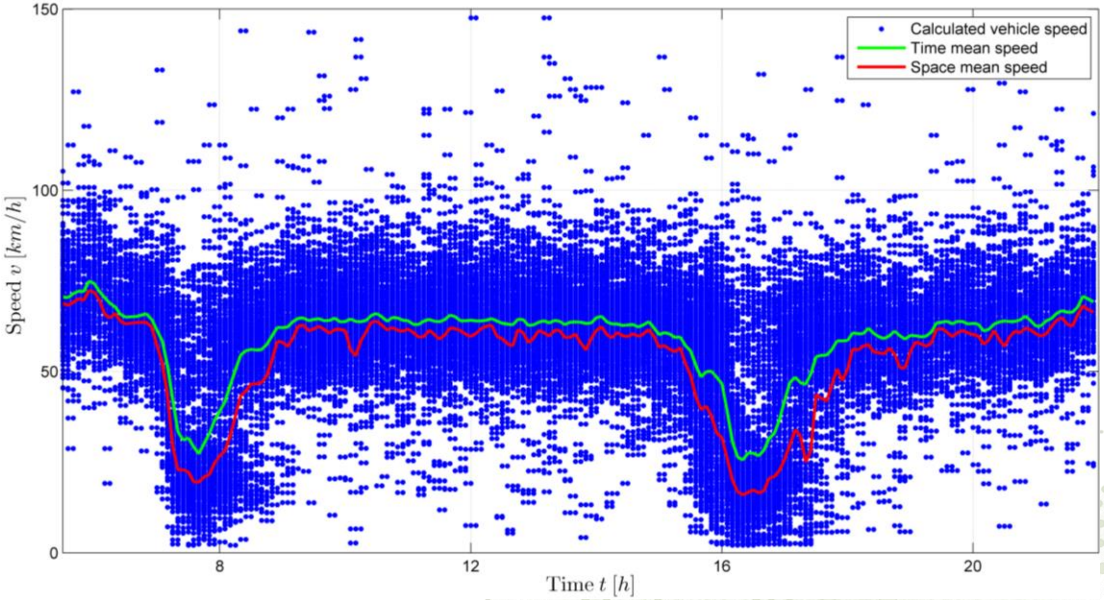
- Big Data represents the information assets characterized by such a **High Volume, Velocity and Variety** to require specific technology and analytical methods for its transformation into Value

(de Mauro et al., 2015)



Space mean speed

- Space mean speed is selected for speed profile calculations as it is considered more accurate
- Space mean speed is harmonic mean of speeds passing a point during a period of time
- Five minute speed profiles
- Seven days per week

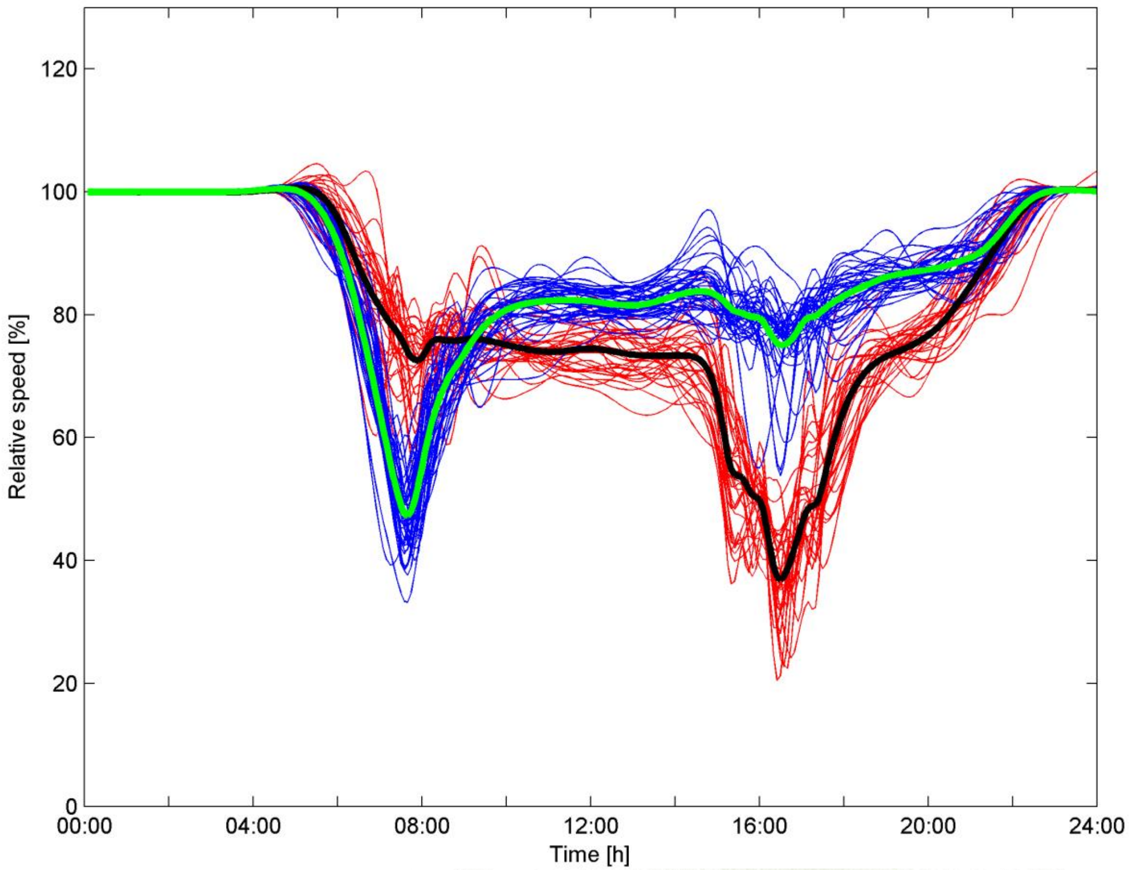


- We also took into account the increase in the overall traffic that exists during summer months (Croatia is touristic country with seasonal peak in traffic during summer months)

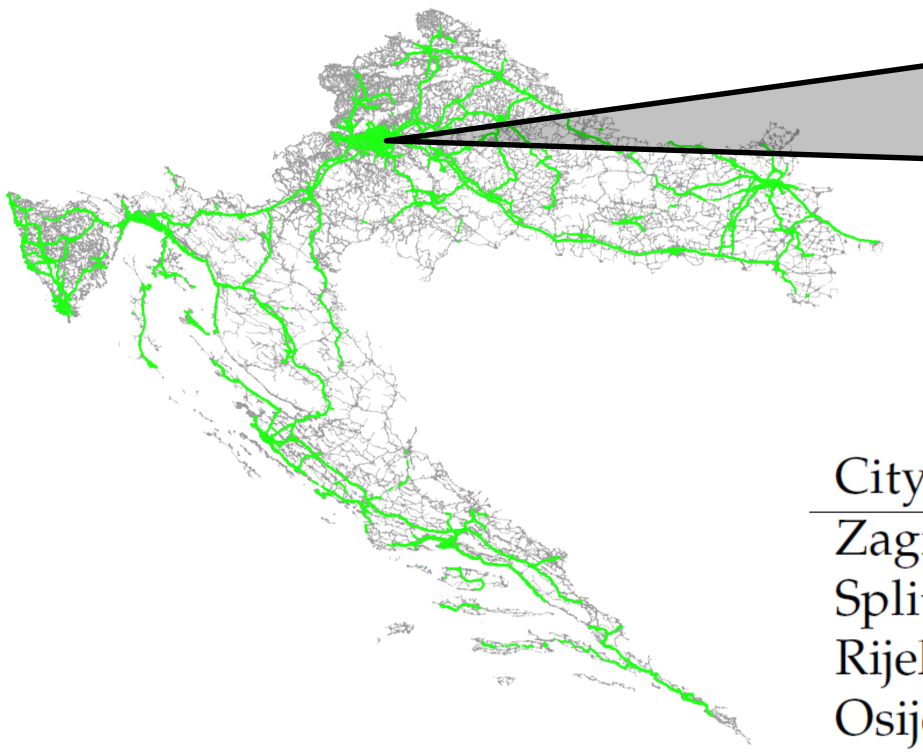
- **Space mean speed**
  - Harmonic mean speed
  - $v_s = \frac{d}{t_s} = \frac{n}{\sum_{i=1}^{n} \frac{1}{v_i}}$

K-means grouping of speed profiles

- 580 000 speed profiles were calculated
- Speed profiles were grouped by k-means algorithm
- 4 096 groups were used
- Speed profiles are grouped to be more easily used in algorithms (such as Dijkstra, to find shortest path)



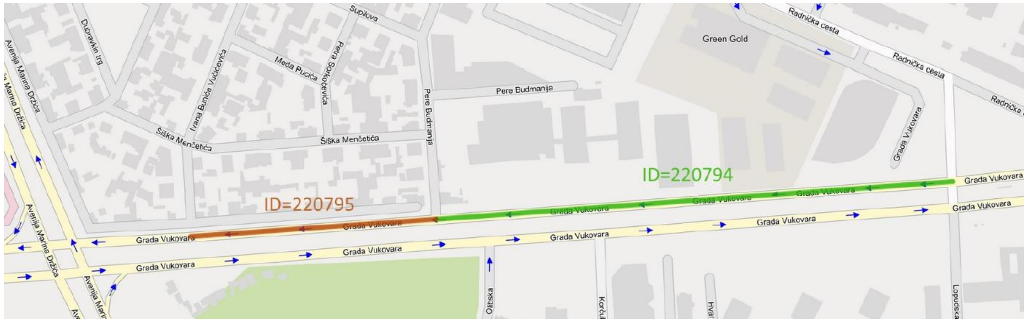
Speed profile coverage

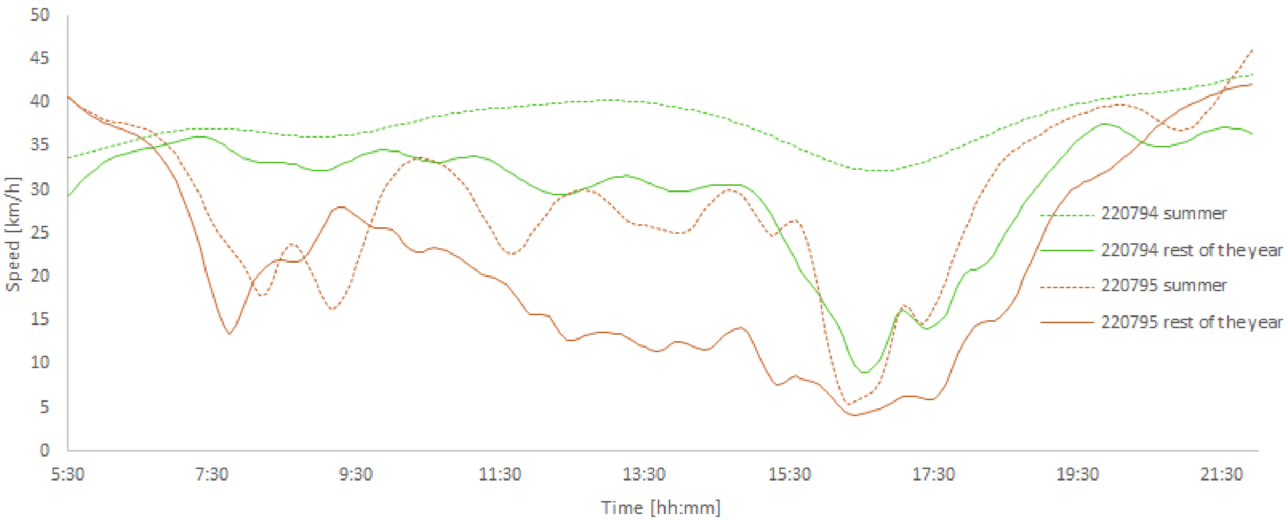


City	$L_s[km]$	$L_r[km]$	$coverage[\%]$
Zagreb	2.791	956	34, 24
Split	242	102	41, 87
Rijeka	443	237	53, 47
Osijek	293	165	56, 39

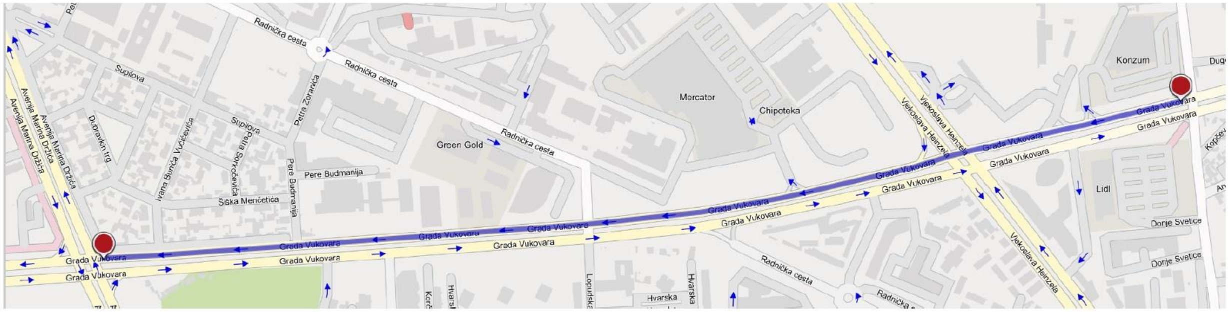
Speed profile example

- Speed profiles for two links in the city of Zagreb
- Separated profiles for summer period of the year (July and August)
- Link 220795 (brown) is closer to the large crossroad





Time dependent shortest path



- Example of one short time dependent route in the city of Zagreb

Summer

Departure time	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.
00 : 00	02 : 55	02 : 55	02 : 55	02 : 55	02 : 55	02 : 55	02 : 55
06 : 00	03 : 02	02 : 53	02 : 52	02 : 52	02 : 55	02 : 54	02 : 39
08 : 00	03 : 30	03 : 47	03 : 50	03 : 51	03 : 38	03 : 00	02 : 41
12 : 00	03 : 41	03 : 39	03 : 44	03 : 38	03 : 52	03 : 09	02 : 55
16 : 30	04 : 35	04 : 11	04 : 40	04 : 40	04 : 45	02 : 58	02 : 46
20 : 00	02 : 58	04 : 09	02 : 50	03 : 10	03 : 06	03 : 09	02 : 48

Rest of the year

Departure time	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.
00 : 00	03 : 12	03 : 12	03 : 12	03 : 12	03 : 12	03 : 12	03 : 12
06 : 00	03 : 08	03 : 09	03 : 07	03 : 11	03 : 05	03 : 11	03 : 00
08 : 00	04 : 39	04 : 49	04 : 34	04 : 29	04 : 46	03 : 17	03 : 15
12 : 00	04 : 30	04 : 24	04 : 19	04 : 19	04 : 59	03 : 37	03 : 18
16 : 30	07 : 05	06 : 22	06 : 50	06 : 34	07 : 38	03 : 17	03 : 14
20 : 00	03 : 35	03 : 24	03 : 38	03 : 39	04 : 03	03 : 25	03 : 23

Calculation time for navigation

- If we use speed profiles for navigation:
  - Urban route inside area of Zagreb is calculated in approx. *0.1 s*
  - From Zagreb to Dubrovnik, we have 3 917 links, 601 km and time dependent Djikstra algorithm needs *2.9 s* for calculation of the best time dependent shortest path solution

Calculation time for Vehicle Routing Problem

- For the real world freight delivery problem with 188 customers we need a lot of processing time only for preparing data.
- If we use speed profiles we need to calculate 84 distance matrices and 84 travel time matrices if the working time of the depot is 7 h. (84 x 5 min intervals = 7 h)
- For generating one matrix we need (188 x 188=35 344) time dependent shortest path calculation.
- For generating (84 + 84=168) matrices we need 50h, or more than two days.
- For industrial purpose this is not acceptable time

Slow down coefficients vs. matrix

- Speed profiles are used as a base for route optimization algorithms in order to predict more precise travel time

- Generally, for urban freight delivery, where we need to find routes to serve all customers by fleet of vehicles, the time response of system has to be completed in minutes (not in hours)

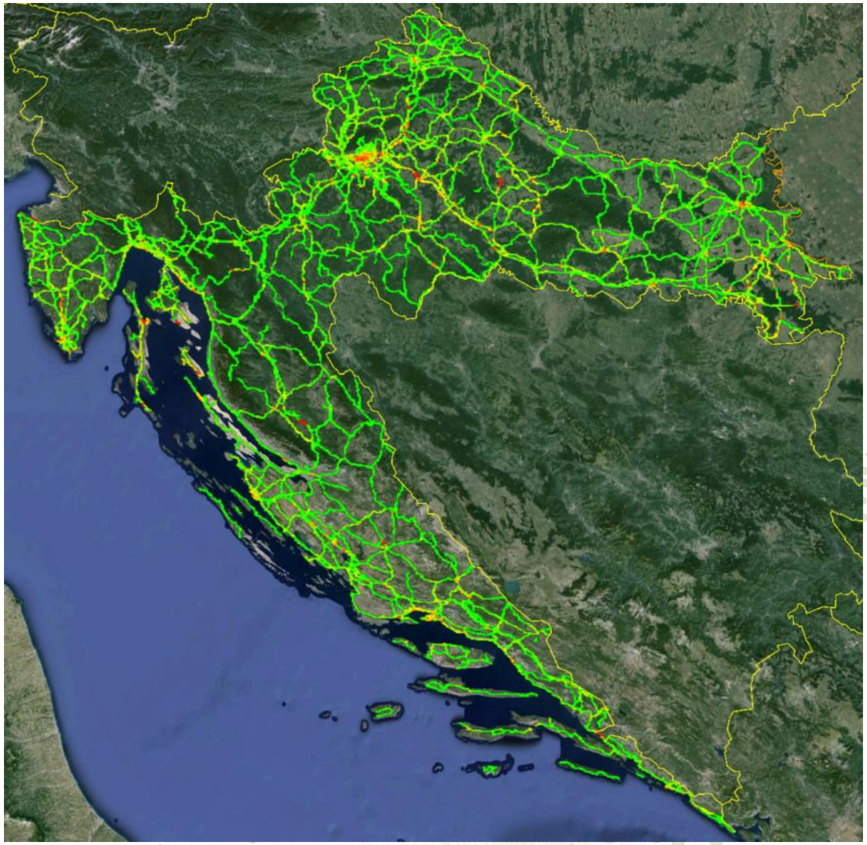
- We can use slowdown coefficients for congested areas instead of matrices and reduce execution time of algorithms

- Slowdown coefficients for polygons with reduction of the time intervals can significantly speed up optimisation algorithms

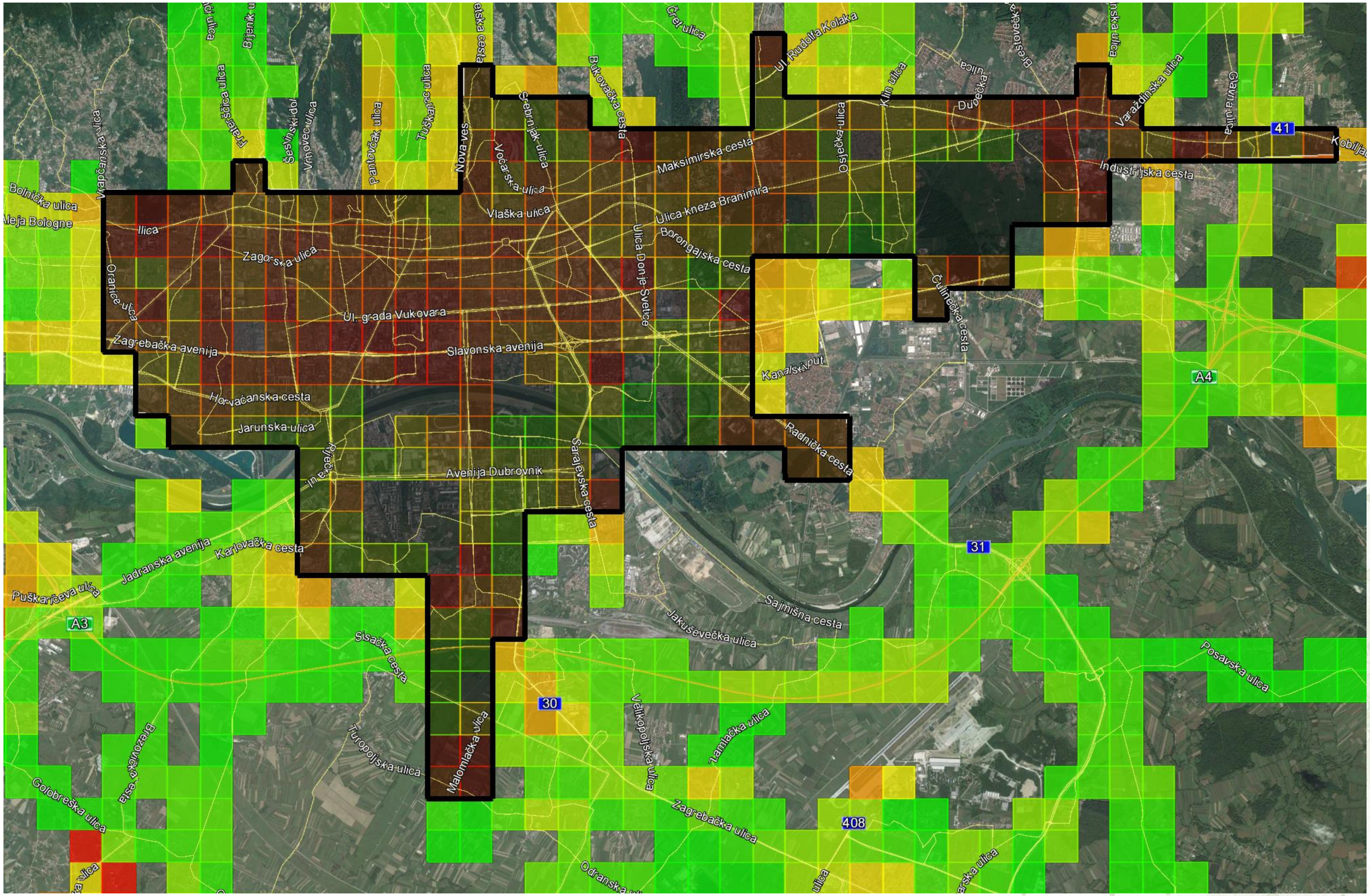
Congested areas

- There are about 36 000 square zones where at least one link with speed profiles is assigned

- The congestion zone is depicted by red colour where the decrease in velocity in comparison to night value is more then 40%

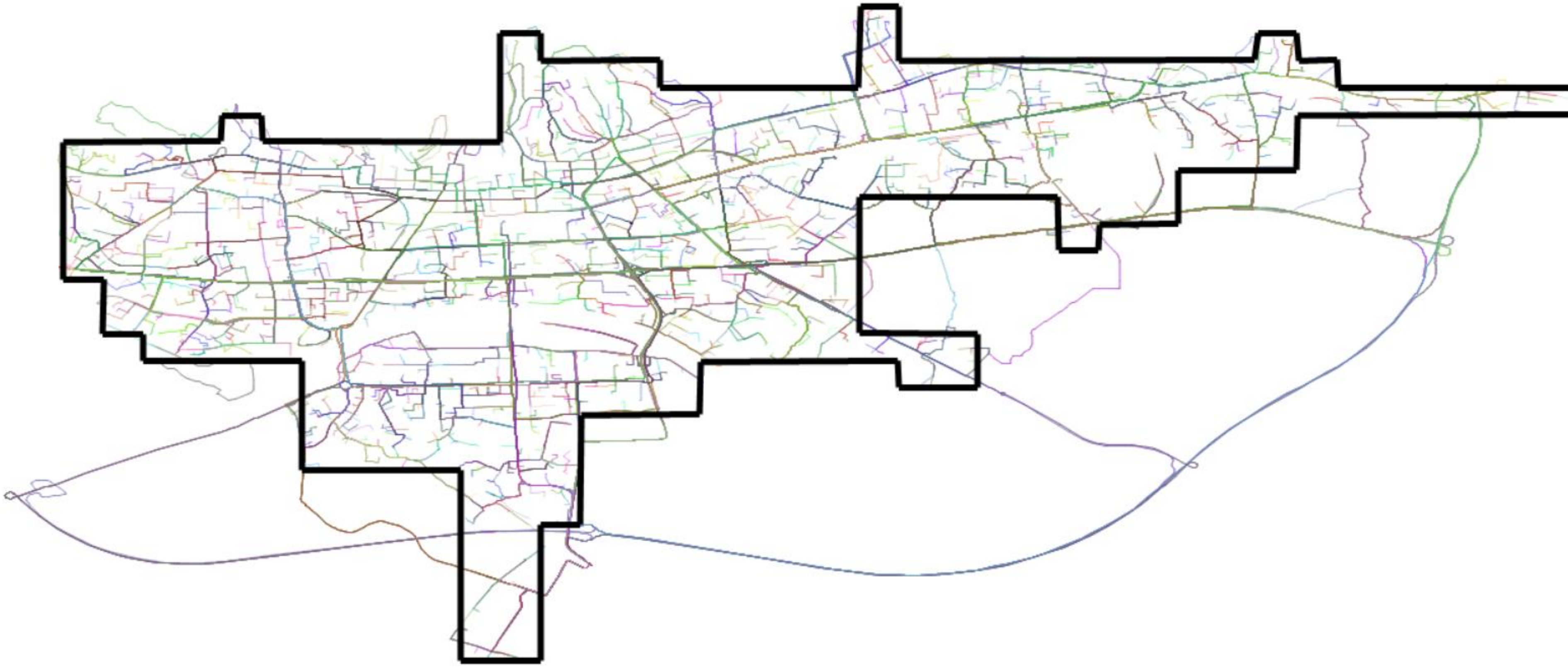


Congested areas (analysis), morphological closing



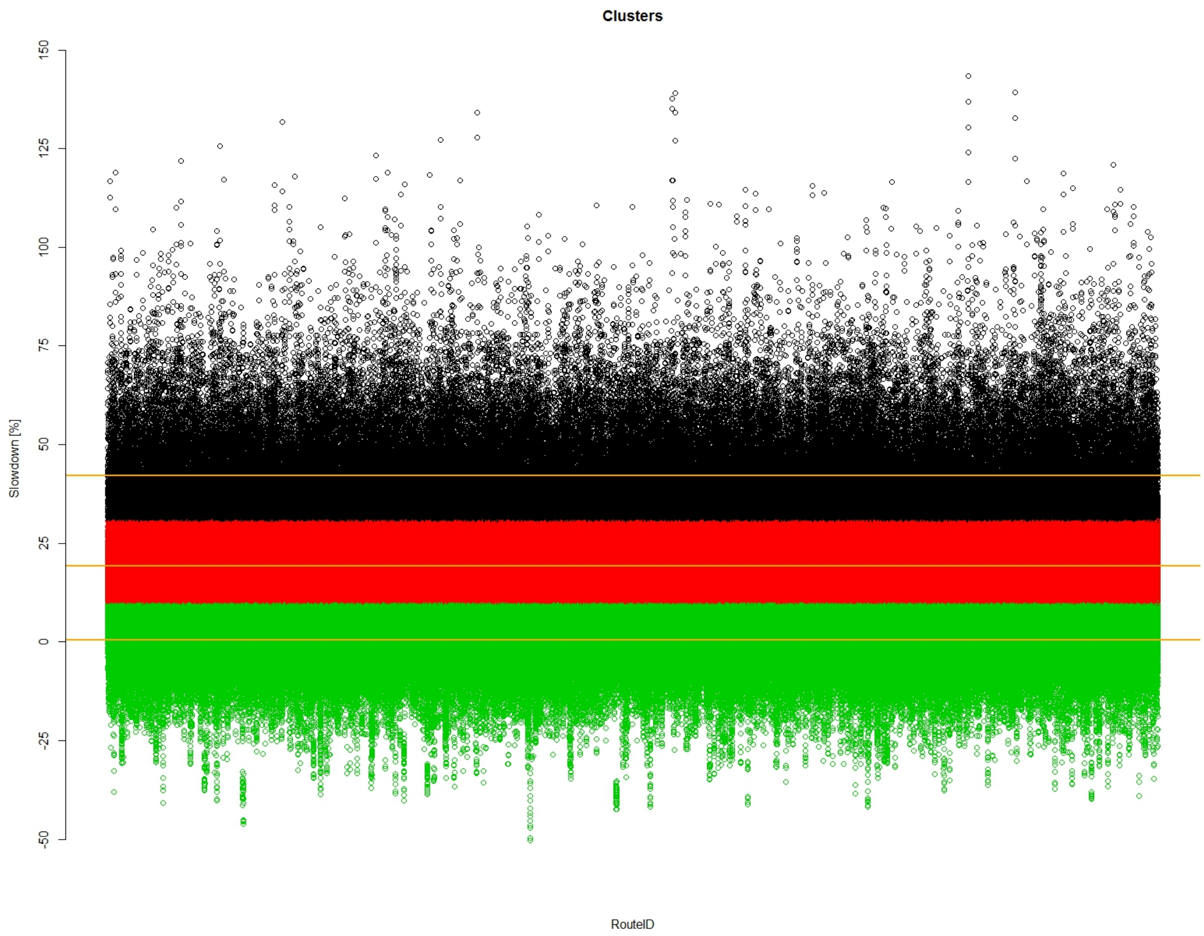
Simulation of routes

- 20 000 ordered pairs of random origin and destination points
- For each pair (49+1) routes are calculated with random departure time



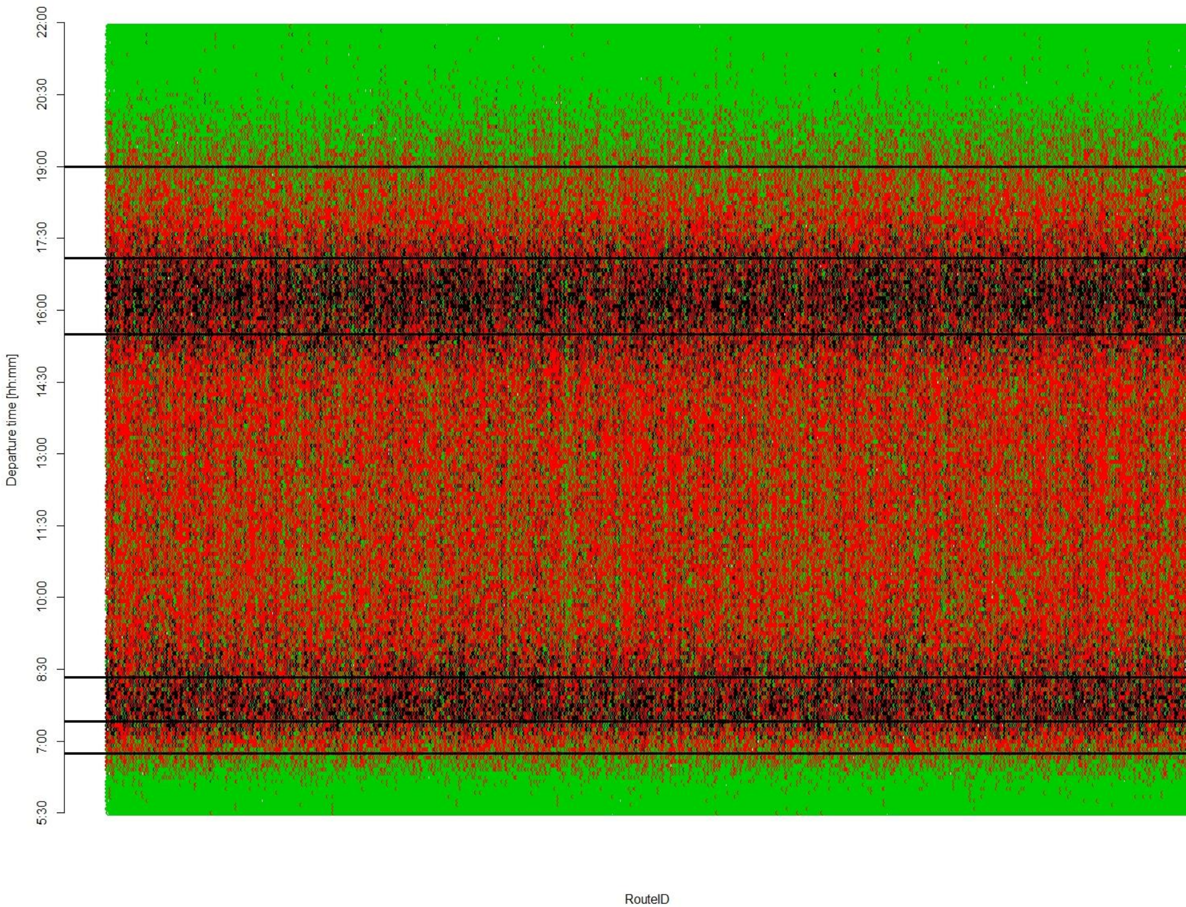
1 million route simulation per polygon

- For each route the increase in travel time with regard to the referent route (midnight route) is calculated
- We expect three typical situations in traffic
  - No congestion
  - Light congestion
  - Heavy congestion
- That's the reason we expect three clusters



Reduction of the time intervals

- Every point on the graph represents one route, where the *route id* is on the horizontal axis and the *departure time* is on the vertical axis
- The colour of a point represents one of the three congestion levels
- Every five minute interval is paired with the most frequent congestion level appearing in that interval
- A new time interval border is made every time the most frequent congestion level changes between consecutive five minute time intervals



Slowdown coefficients

- A slowdown coefficient is computed for each of the new time intervals
- 199 five minute time intervals reduced to 7 time intervals

Summer Interval	Summer Slowd.[%]	Rest of the year Interval	Rest of the year Slowd.[%]
05 : 30 – 06 : 25	1,12	05 : 30 – 06 : 45	−0,09
06 : 25 – 07 : 20	10,37	06 : 45 – 07 : 25	17,90
07 : 20 – 09 : 30	18,16	07 : 25 – 08 : 20	31,66
09 : 30 – 15 : 30	13,73	08 : 20 – 15 : 30	18,08
15 : 30 – 16 : 40	16,65	15 : 30 – 17 : 05	31,58
16 : 40 – 18 : 25	10,53	17 : 05 – 19 : 00	16,24
18 : 25 – 22 : 00	0,36	19 : 00 – 22 : 00	1,42

Experiment: driven routes in Zagreb in comparison with calculated routes with slowdown coefficients

Length	Number of driven routes	Driven routes [min]
< 2 km	71	3,24
2 km - 10 km	185	13,13
> 10 km	30	27,56
	286	12,19

Length	Speed profile AVG	Coefficients AVG	Night speed AVG	Industrial navigation AVG
< 2 km	15,63%	23,46%	7,07%	-31,98%
2 km - 10 km	0,88%	-1,33%	-15,63%	-29,79%
> 10 km	-1,41%	-4,47%	-14,50%	-14,77%
	4,30%	4,49%	-9,87%	-28,76%

Length	Speed profile DEV	Coefficients DEV	Night speed DEV	Industrial navigation DEV
< 2 km	30,73%	40,20%	36,20%	19,70%
2 km - 10 km	21,08%	26,05%	22,95%	20,22%
> 10 km	17,42%	22,09%	22,25%	21,25%
	24,34%	31,70%	28,42%	20,72%

Conclusion

- GPS data is a good data source for prediction of precise travel time

- Speed profiles are derived by processing recorded GPS data and they are:
    - Very good for direct use in navigation
    - Essential for generating slowdown coefficients in polygon

- We proposed a method for calculating slowdown coefficients

- Experiments show that using slowdown coefficients can improve time prediction for freight delivery

End

Thank you for your attention!

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SORDITO project is co - funded by the European Regional Development Fund (R.C.2.2.08-0022)